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MODIS-HIRIS Ground Data Systems Commonality Report

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1. INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

The High Resolution Imaging Spectrometer (HIRIS) and Moderate Resolution Imaging Spectrometer (MODIS) Data Systems Working Group was formed in September 1988 with representatives of the MODIS Data System Study Group and the HIRIS Project Data System Design Group to collaborate in the development of requirements on the Earth Observing System Data Information System (EosDIS) necessary to meet the science objectives of the two facility instruments. A major objective was to identify and promote commonality between the HIRIS and MODIS data systems, especially from the science users' point of view. A goal was to provide a base set of joint requirements and specifications which could easily be expanded to a Phase-B representation of the needs of the science users of all Eos instruments. The set of documents delivered to EosDIS by the working group is illustrated in Figure 1.

1.2 SCOPE

The working group used as input the ongoing efforts of the HIRIS and MODIS facility instrument data system design activities and defined the scope of the current task as follows:

a. To develop a single Level-I Functional and Performance Requirements Document characterizing the ground data systems for both the MODIS and HIRIS instruments.

b. To provide a complete set of preliminary HIRIS and MODIS documents, namely, Level-II Functional Requirements, Operations Concepts, and System Specifications. These documents follow similar approaches and outlines and use common content where feasible within commonality and resource constraints.

c. To document points of commonality and difference between the Level-II Requirements, Operations Concepts, and Systems Specifications for the ground data systems for the MODIS and HIRIS instruments at their present state of development.

The teams should maintain contact with the follow-on Phase-B effort to ensure that the concepts developed are understood and requirements are not compromised. The tasks listed below were not within the scope of this task, but should be accomplished during Phase B:

a. To trace all differences in the lower-level documents to identified functional sources of differences.

b. To recommend changes to operations concepts and systems specifications which will increase commonality, while still meeting the identified requirements.

c. To expand the joint requirements and specifications to cover the broader Eos community.

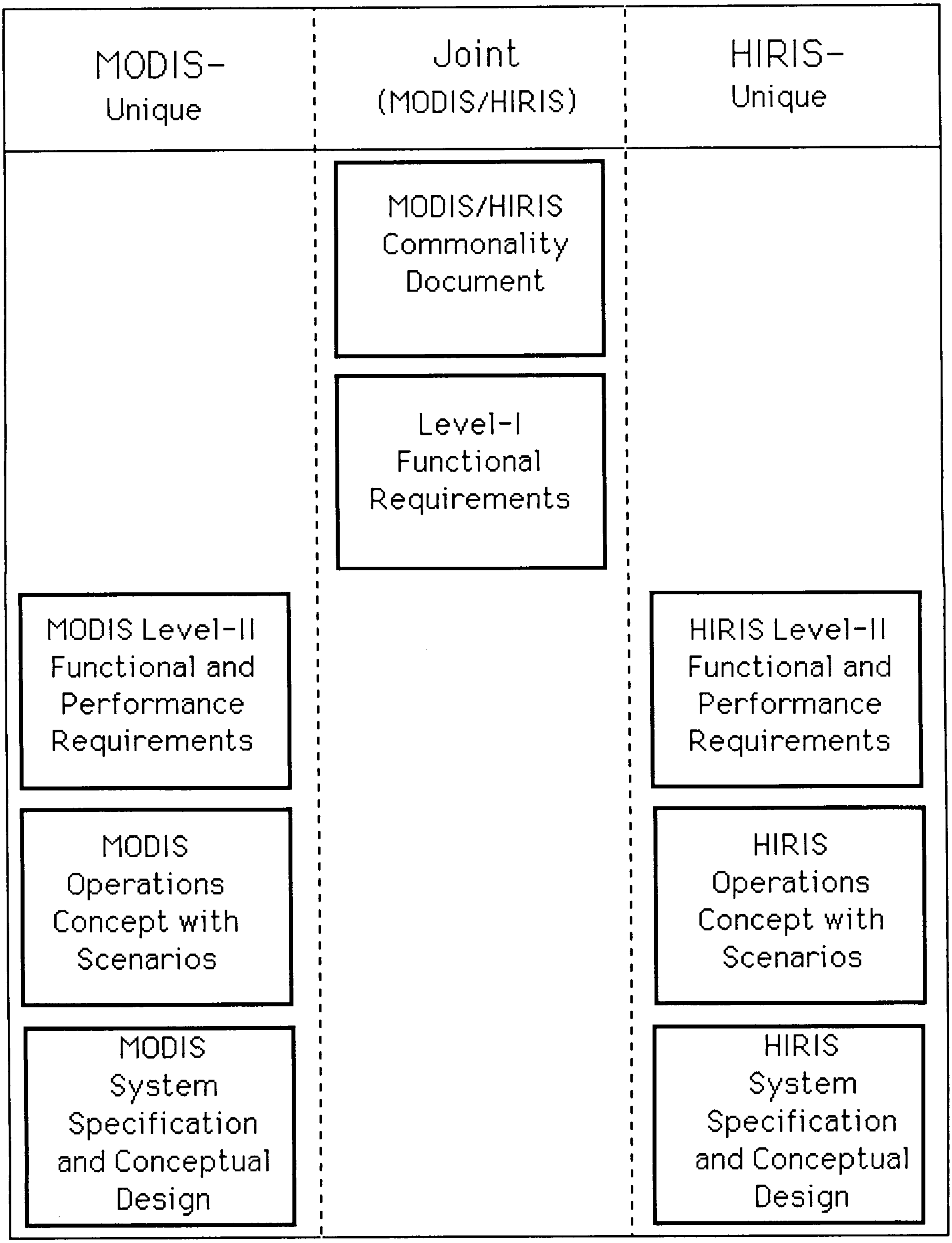

Figure 1. Documents to be Delivered to EosDIS

1.3 MODIS/HIRIS DATA SYSTEM SIMILARITIES

There are many similarities in the planning, scheduling, control, and monitoring of the MODIS and HIRIS instruments. The planning and scheduling use the same guidelines set down by the International Investigator Working Group (IIWG), the Investigator Working Group (IWG), and Science Team Leaders. The schedule of events and the timeliness of events leading up to the generation of command loads are also similar. Both require that schedules be approved through an iterative interface with the EOS Mission Operations Center (EMOC) and that commands be generated approximately one week before uploading of the command by the Platform Support Center (PSC). They both allow for the updates of schedules and commands for targets of opportunity and instrument emergencies. Both HIRIS and MODIS use science data as well as engineering data to monitor instrument health and safety, although the science data may be provided somewhat differently.

The processes for developing, validating, and maintaining algorithms for the production of standard products are the same for HIRIS and MODIS. The procedures and facilities for the generation and delivery of standard products are the same, although routing and volume differ. In many cases, even the algorithms used for processing will be similar. The handling of special data products is identical. The definition, structure and access to catalogs, metadata, and browse data, and the archive itself, are identical. The strong allegiance to the use of standards for software, data identification, and formatting, and processing is identical. Both HIRIS and MODIS specify modular, expandable architectures for the processing environment emphasizing the use of standard commercially available general purpose and special purpose computers, communications, and storage media.

1.4 MAJOR SOURCES OF DIFFERENCES

1.4.1 Observatory Versus Survey Use

The survey mode employed by MODIS assumes full-time operation of the instrument in acquiring data, limited only by such operational considerations as darkness. The observatory mode employed by HIRIS assumes that data are taken primarily in response to a specific observation request. The observatory mode is employed because the full-time use of the spectral and spatial resolution of the HIRIS instrument generates an enormous volume of data at a rate exceeding the planned capabilities of the platform and the downlink communications. The ability of the science community to use this volume of data meaningfully is insufficient to justify the new technology development required for expansion of the platform and downlink capacity to allow full-time operation of the HIRIS instrument. The MODIS-N instrument operates on a full-time-on duty cycle, taking data at all times, with the reflected-energy and emitted-infrared channels operating during daytime, and the infrared channels operating during nighttime. The MODIS-T instrument will operate full-time during daytime only; however, MODIS-T pointing operations require significant planning and control support. Operation of the HIRIS instrument in the selective observatory mode imposes an even greater throughput and complexity demand on the entire instrument planning and control cycle.

1.4.2 Anticipated Differences in Platform Support

Limited duty cycles for the HIRIS instrument reduce the average data output, but special on-board processing must be employed to reduce the instantaneous transfer rate from the instrument from its maximum of 410 megabits per second to less than 280 megabits per second. The planning and command support for the spectral editing and spatial editing or averaging typical of the reduction processing further exacerbate the ground planning and control complexity.

Even at the reduced rate, the platform and downlink services including the ground Tracking and Data Relay Satellite System (TDRSS) processors employ a separate data path for the HIRIS data, with slower guaranteed delivery of the Level-0 data stream to the Ground Data System (GDS). To accommodate requirements for real-time and near-real-time availability of the science data in field experiment support and in instrument health monitoring, a separate low-rate science stream is created on-board which uses the same data path as the full MODIS science stream on the platform and on the ground.

Such a separate stream is not required for MODIS since the full data stream can be downlinked to meet real-time and near real-time requirements. The specification of data to be included in the sub-sampled HIRIS data adds once more to the planning and control load.

1.4.3 Essential Performance Characteristics

a. Data Rate: The long-term average data rate of MODIS is higher than the assumed long-term average data rate of HIRIS, but the instantaneous transfer rate for MODIS is within the performance specifications for the platform Local Area Network (LAN) and thus the entire MODIS data stream can be downlinked to meet the real-time and near-real-time requirements, with selection on the ground of the subset of science data to be processed beyond Level-0 for real-time and near-real-time uses.

b. Spatial Resolution: calibrated products from the 250 to 1000 meter MODIS data and from 30 meter HIRIS data impose differing demands on the spatial calibration process. Due to the dramatic difference in resolution, the use of common grids for the two instruments, except for comparisons, is unlikely.

1.4.4 Differing Operational Assumptions

a. We assume a different geographic distribution of teams, team leader, and facilities for MODIS and HIRIS. The MODIS control functions may be located at Goddard Space Flight Center (GSFC) and may be collocated with the EMOC. The HIRIS control functions may be distributed, with functions located near respective engineering or operations support facilities.

b. Standard Level-2+ products for HIRIS are generated on request, while for MODIS Level-2+ products are routinely generated for all data. Both sets of products use standard algorithms.

c. Both HIRIS and MODIS identify the need for continuing instrument engineering support during the operations phase. Due to institutional and geographic considerations, the MODIS engineering support is tightly coupled with the team leader facility at GSFC, while the HIRIS engineering and calibration facility is assumed to be at the Jet Propulsion Laboratory (JPL), geographically separated from, although closely functioning with, the team leader facility.

d. Both HIRIS and MODIS identify the need for science and calibration algorithm development support beyond the team member computing facilities and independent of the production processing facilities. Operationally, HIRIS assumes this is collocated with the calibration laboratory, while MODIS assumes this to be collocated with the team leader computing facility.

2. LEVEL-I REQUIREMENTS SIMILARITIES AND DIFFERENCES

The Level-I requirements for HIRIS and MODIS are very similar and are documented in detail in the joint HIRIS/MODIS Level-I Functional Requirements Document. The functional requirements are identical. The major differences are in the performance requirements and are summarized below.

The differences in the Level-I performance requirements are limited to volume and sizing requirements. These are driven by the different data rates for the instruments (see Table 1). The MODIS-N and MODIS-T instruments will operate on 100% duty cycles (100% daytime for the reflected-energy channels; 100% daytime and nighttime for the emitted-energy channels). The HIRIS instrument will only take data in response to user requests; on the order of 7,200 data acquisition requests are anticipated per month.

The average HIRIS data processing and archiving granule, or scene, is assumed to contain the equivalent of 90 bands, 800 by 1250 pixels, and 12 bits of quantization, yielding a processing volume (at 16 bits) of 182 megabytes or 1.5×10^9 bits. The most common HIRIS user request will be for a small number of scenes. The typical user request for MODIS data will range from 10^{10} to 10^{12} bits, with varying amounts of global-coverage or regional-coverage data being ordered.

The mechanisms for monitoring the science data in near-real time are different in the cases of MODIS and HIRIS: HIRIS is able to subsample two to six bands, for a low-rate LAN use of 1 Mbps; MODIS will use the platform LAN, but may be unable to subsample on board, requiring that 100% of the data be available on the ground to monitor any of the spectral bands (assume four each for MODIS-T and MODIS-N).

There are some differences in the spectrally and spatially subsampled browse data volumes for the two instruments: HIRIS will occupy 200 kilobytes per scene (46×10^6 bytes per day), while MODIS will offer Level-1/2/3 browse data products totalling 400×10^6 bytes per day.

Table 1
Representative MODIS and HIRIS Data Rates

CATEGORY	RATE (Mbps)
HIRIS long-term average:	3
MODIS-T long-term average:	3.5
MODIS-N long-term average:	6
HIRIS worst-case 2-orbit:	10
MODIS-T maximum (daytime):	7
MODIS-N maximum (daytime):	9
MODIS-T minimum (nighttime):	<1
MODIS-N minimum (nighttime):	1.5
HIRIS quick-look science:	<1
HIRIS burst rate	280

3. LEVEL-II REQUIREMENTS SIMILARITIES AND DIFFERENCES

3.1 THE INSTRUMENT SUPPORT TERMINAL (IST) FUNCTIONAL AND PERFORMANCE REQUIREMENTS

3.1.1 IST Functional and Performance Requirement Similarities

The functional and performance requirements of the MODIS Information, Data, and Control System (MIDACS) IST and the corresponding HIRIS Instrument Control Center (ICC) and IST functions are very similar. Commonality exists in the approach to a mechanism to enter observation requests and their updates, perform conflict resolution between the science team and the ICC, and to display planning and scheduling data. These functions are required by both HIRIS and MODIS for the coordination of the planning and scheduling of instrument operations.

Another similarity is the requirement to display the planning and scheduling parameters and events, the resource allocations, and to provide a path for communication between the science and calibration team, and the instrument operations team. Similarities exist in the use of this path for transmission of algorithms, calibrations parameters, and health and safety monitoring parameters. Command requests also are issued using this mechanism.

Commonality exists for the display and reporting of instrument health and safety parameters, science data, and long-term trends. Both ground systems require the use of workstations for the numerous functions of the IST.

3.1.2 IST Functional and Performance Requirement Differences

There are no major identifiable differences in the functions and performances of the MIDACS and HIRIS IST's (see Table 2).

Table 2
Similar And Different IST Requirements And Performances

REQUIREMENT/PERFORMANCE	SIMILAR	DIFFERENT
Communication	x	
Science Team/ICC	x	
Coordination	x	
Planning & Scheduling	x	
Monitoring	x	
Reporting	x	
Displaying	x	

3.2 ICC FUNCTIONAL AND PERFORMANCE REQUIREMENTS

The two sections presented below present the similarities and differences in the ICC functional and performance requirements for the MODIS and HIRIS ground data systems. As seen below, the majority of these requirements are similar due to the EosDIS Level-I requirements. Table 3 presents a brief overview of the similar and different functions and performances.

3.2.1 ICC Functional and Performance Requirement Similarities

There are many similarities between the required MODIS and HIRIS ground data system functions and performances for control of their respective instrument. Two of the drivers causing the similarity are the dependencies on the NASA platform and on the EosDIS Level-I requirements. Both ground data systems require a control center at which the instrument operations can be planned, scheduled, controlled, and monitored.

Both ground systems require that the ICC have the capability to support the planning and scheduling of the instrument operations. Both ground systems are required to support multiple science users, the science team, and other non-team members. The ingest of observation requests from these users requires a mechanism to maintain priorities and resolve conflicts. This requirement, in turn, results in a requirement for an interface with the ICC and a science team leader for approval of requested instrument observation operations, and with the EMOC and science team leader for conflict resolution. Both ICC's are required to follow similar scenarios for the planning and scheduling of instrument operations.

Both the MODIS and HIRIS ICC's use instrument simulations in generating schedules responsive to requests and meeting allocated resources. Both centers will accommodate updates to any request as well as requests for targets of opportunity. A process to generate an exception-free schedules using an iterative method is common to both MODIS and HIRIS ICC's. The timeliness of the schedule generation is similar for MODIS and HIRIS, being approximately three weeks before schedules are implemented.

Another commonality is the generation of command loads from the approved schedules one week before upload. These command loads will be sent to the EMOC with mission information detailing the commands sent to the rest of the ground system. Both are required to support the real-time and/or emergency commanding of the instrument in the case of instrument anomalies. Both require that delays be less than ten seconds for the generation of such commands for dissemination to the EMOC.

Both centers are required to monitor the instrument behavior using ancillary data, engineering data, and science data. Evaluation of these data will be performed in a quick-look (real-time or near real-time) sense with additional analysis provided by long-term trending. A history of all instrument operations will be maintained by the ICC's and the Data Archive and Distribution System (DADS). In the case of anomalies, the ICC's are required to involve a cognizant science team member or leader for corrective actions. Both ICC's are required to generate reports that detail the use and health and safety of the instrument and to disseminate this information and data to respective interested parties such as the EMOC and science teams.

3.2.2 ICC Functional and Performance Requirement Differences

The major difference in the requirements for the ICC functions and performance is in the acquisition, generation, and routing of science data for "quick-look" real-time or near real-time monitoring of the instrument (see Table 3).

Both HIRIS and MODIS are required to quickly obtain science data for health and safety monitoring and field experiment support, but the sampling and processing techniques are different. For HIRIS, the quick-look data is subsampled within the instrument, and combined with the low-rate engineering data stream for transmission to the ground. For MODIS, the quick-look data is subsampled from the full set of observational data that is routinely sent to the ground.

Table 3
Similar and Different ICC Requirements and Performances

REQUIREMENT/PERFORMANCE	SIMILAR	DIFFERENT
PLANNING	x	
Coordination	x	
Guidelines	x	
Timeliness	x	
SCHEDULING	x	
Initial schedule	x	
Coordination	x	
Iterative Conflict Resolution	x	
Timeliness	x	
COMMAND GENERATION	x	
Command load generation	x	
Real-time Commands	x	
Emergency Commands	x	
Timeliness	x	
MONITORING	x	
Engineering data	x	
Ancillary Data	x	
Science Data	x	
Timeliness	x	
REPORTING	x	
SIMULATIONS	x	
QUICK-LOOK REQUIREMENT	x	
TIMELINESS	x	
SAFING COMMAND TIMELINESS	x	

3.3 TMCF FUNCTIONAL AND PERFORMANCE REQUIREMENTS

3.3.1 TMCF Functional and Performance Requirements Similarities

The Team Member Computing Facility (TMCF) for both instruments is assumed to be geographically distributed. The MODIS Team Leader Computing Facility (TLCF) and the HIRIS Calibration Analysis and Science Support Laboratory (CASSL) appear to be functionally equivalent.

The MODIS Calibration Support Team (CST) and HIRIS Calibration Analysis Laboratory (CAL) have equivalent functions with regard to calibration, such as developing calibration algorithms, maintaining the accuracy and stability of the calibrations, and understanding the physical basis for changes in instrument behavior. Both MODIS and HIRIS calibrations will need to be maintained in such a way that higher-level processing is not delayed and that instrument accuracy is not compromised.

3.4 CDHF FUNCTIONAL AND PERFORMANCE REQUIREMENTS

3.4.1 Similarities

The Central Data Handling Facility (CDHF) accepts Level-0 data from the Data Handling Center (DHC) for processing. The Level-0 data contains instrument science data, calibration target data and instrument engineering data. The CDHF processes all data to Level-1; more than one Level-1 product may be defined.

The Level-2 processor receives Level-1 data and any ancillary data necessary for the Level-2 processing step. The Level-3 processor receives Levels-1 and -2 and any ancillary data necessary for the Level-3 processing step. The Level-4 processor receives Levels-1, -2, and -3 data and any ancillary or correlative data necessary for the Level-4 processing step. The CDHF sends all standard data products to the DADS for archival.

3.4.2 Differences

For the MODIS CDHF, all standard data products will be produced for all data taken within the product's domain. For the HIRIS CDHF, Level-2 and higher data products will be produced when requested, or periodically to allow product re-validation.

The MODIS CDHF will be required to provide near-real-time data products for the support of field experiments. HIRIS will send near-real-time data directly to the ICC and CAL, which will support field experiments.

3.5 DADS FUNCTIONAL AND PERFORMANCE REQUIREMENTS

3.5.1 Functional Requirement Similarities

Both systems will provide for the display of directory, catalog, browse, metadata, and other inventory information pertaining to archived data products. Data sets will be retrievable as a function of this information or as a result of a retrieval command for a specific image or granule. Users will be able to obtain status information on their outstanding queries. Accounting information for user activity levels and requested products will be generated and reported.

Data sets will be stored on optical tape, optical disk, or other media appropriate for the data quantities. Requested data sets will be transmitted to the user on specified media.

Data sets and other specified information will be purged after specific periods ranging from six months to four years, after the information is sent to a long-term archive.

HIRIS and MODIS will need to ensure the DADS receipt of the necessary browse, catalog, and metadata for the special products received from the varied sources. HIRIS and MODIS will also have to ensure the consistent application of quality control and certification measures to the processing algorithms and generation of the descriptive data.

3.5.2 Functional Requirement Differences

The MODIS and HIRIS DADS will receive the majority of data sets from the CDHF; but, at least initially, MODIS will be expected to generate more higher-level products than HIRIS.

3.5.3 Performance Requirement Similarities

Both systems will update the DADS in terms of data sets and descriptive data as these data types are received from the CDHF or other sources. Off-line media will be prepared and shipped to requesting users within 24 hours of query receipt.

3.5.4 Performance Requirement Differences

Differences in the DADS are based on the different volumes of data to be archived and distributed.

4. OPERATIONS CONCEPT COMMONALITY

4.1 INSTRUMENT CHARACTERISTICS

4.1.1 Instrument Similarities

Both instruments have a heavy emphasis on characterizing the surface of the Earth (land, ice, and oceans), although they will have capabilities for characterizing the atmosphere, clouds, and aerosols. MODIS-N will have significant atmospheric characterization capabilities.

HIRIS and MODIS are imaging spectrometers. MODIS-N differs in its non-uniform spatial and spectral resolutions, partial spectral coverage, and some polarization determination capabilities. HIRIS visible and near infrared detector and MODIS-T have nearly the same spectral resolution and coverage.

Both MODIS and HIRIS will be on the same platform. They will be capable of simultaneously observing the same region of the Earth. Both MODIS and HIRIS will produce low-rate streams of data from their science data, in near-real time, for purposes of monitoring instrument health and supporting field experiments.

4.1.2 Instrument Differences

MODIS will continuously acquire data in all channels while observing in daylight. MODIS thermal-IR channels will continuously acquire data, over both daytime and nighttime regions. HIRIS will acquire data only in the spectral channels specified for a given data take.

The wide swath of the MODIS instrument scan will provide complete coverage of the Earth every one to two days. Even if HIRIS were to acquire continuous daytime data, its narrow swath, combined with data rate limits imposed by EosDIS and TDRSS, would make it impossible to acquire complete coverage of the Earth in less than a year.

MODIS-N has 15 thermal-infrared channels that will have significant capabilities for characterizing the atmosphere, as well as the surface. HIRIS has no such channels.

HIRIS necessarily has more flexibility in the ways it may acquire data than MODIS does. HIRIS flexibility in pointing, in image motion compensation, and in on-board editing of the data stream, are examples.

MODIS is a survey instrument that will continuously map the Earth. HIRIS is an observatory instrument that will acquire data, on request only, over specified regions of the Earth. The only interruptions to MODIS observations will be for calibration and maintenance.

HIRIS will produce its subsampled "quick-look" data stream, for near-real-time instrument monitoring, on board the platform, to allow the quick downlink not possible for the full science data stream. MODIS will produce its equivalent products on the ground, and can potentially produce a near real-time product from the full data stream, unlike HIRIS.

GSFC will be responsible for operations of both MODIS and the platform it is located on. JPL will be responsible for operations of the HIRIS instrument, which will be on a GSFC-operated platform, thus changing the communication requirements for operational support.

4.2 PLANNING AND SCHEDULING

The routine planning and scheduling operations concepts for the MODIS and HIRIS data systems are quite different: the MODIS-N and MODIS-T instruments are always taking data unless directed otherwise; the HIRIS instrument only takes data in response to a direct request. The result of this difference is a significant difference in the volume and complexity of the planning and scheduling activity and the resources required to support it.

The physical location of the ICC will be different for these instruments, resulting in small differences in communications between internal and external ground systems.

4.2.1 Planning and Scheduling Similarities

There are many similarities in the procedures for planning and scheduling the MODIS and HIRIS instruments. Both procedures use the guidelines set forth by the IIWG, IWG, and Science Team Leaders that give a long-term plan for instrument use. They both depend on the guidelines and operational resources received from the EMOC. The schedule and the timeliness of events leading up to the generation of command loads are also similar, in part due to the dependency on the EMOC and other Customer Data and Operations System (CDOS) facilities. Both procedures develop an initial schedule and require that schedules be approved through an iterative conflict resolution process. This resolution process requires an interface with at least the science team leader and EMOC.

The handling and content of an observation request, and the path that it takes to the ICC, are still under discussion; but, both require that all requests be approved by the Science Team Leaders. These requests will be sent directly from team members or

through the Information Management Center (IMC) for other types of users. The requests contain data for a unique observation or time-line changes to support activities such as instrument calibration. Both the MODIS and HIRIS ICC's will use these requests in simulations of the instrument to check environmental and instrument capabilities to meet the request.

The planning and scheduling procedures of both instruments allow updates to be made even after an approved schedule has been made. Using the schedules, both MODIS and HIRIS produce mission planning information for the use by other internal MIDACS or HIRIS Ground Data System (HGDS) facilities. Once the schedule has been approved, commands will be generated approximately one week before the command is uploaded by the PSC. Updates can be issued both before and after the implementation of commands on board, and are treated similarly.

The DADS will be used to archive planning and scheduling information for both MODIS and HIRIS.

4.2.2 Planning and Scheduling Differences

The observatory mode of use of the HIRIS instrument, in response to specific requests, reduces the overall volume of data from the instrument, but dramatically increases the number and volume of requests for instrument activity to be planned and scheduled. The increased number of requests combines with the variety of operational modes of the instrument to increase the likelihood of conflict and the need for conflict resolution procedures in scheduling the instrument. To ease the burden on the team leader for the HIRIS instrument in approving the instrument planning, routine organization and preparation support, including preliminary conflict resolution based on science-team-defined procedures and priorities, are provided by operations personnel.
Although the MODIS-T, because of its tilt capability, has more significant planning and scheduling requirements than MODIS-N, neither approaches the HIRIS level of demand on planning and scheduling.

4.3 CONTROLLING AND MONITORING

The following sections detail the similarities and differences in the control and monitoring operation concepts of MODIS and HIRIS. The control of each instrument is different due to the functional and physical differences in design and required use.

4.3.1 Control and Monitoring Similarities

The controlling of MODIS and HIRIS is the same in the context of a command load transmitted to the EMOC for inclusion into the platform command load.

Both concepts allow for the updates of commands for targets of opportunity and instrument emergencies. Both ground data systems will monitor the health and safety of the instrument using engineering, ancillary, and subsampled science data, although the handling of the science data is quite different. Both concepts may use science data in the near-real time for support of field experiments. Both concepts rely on the DHC for the reception of engineering and ancillary data.

4.3.2 Control and Monitoring Differences

Because of the differences in monitoring science data, only HIRIS will generate command loads to select science data for transmission on the LAN.

Because of the need to reduce the instrument data rate, only HIRIS will generate command loads to select science data to be included in the high-rate science stream. Note that the possible future inclusion of data compression on board could alleviate this need.

The monitoring of science data for both instruments may be essentially the same in function, but the methods of obtaining the data are different. Both concepts use quick-look data, but the terminology of quick-look is different for MODIS and HIRIS concepts. HIRIS quick-look indicates a separate stream to support near-real-time use of the data. MODIS quick-look indicates a subsampling of the full science data stream received and used in real time or near-real time. The MODIS quick-look science data will be selectable on the ground at the MIDACS, while the HIRIS quick-look data is selected in the space segment via command loads and combined with the low-rate engineering data stream. All of the MODIS science data, possibly priority playback data, will be available to the science team member for selection of four channels for health and safety monitoring and 15 channels for support of field experiments (each, for MODIS-N and MODIS-T). The HIRIS quick-look data contains from two to six channels and will be sent on the low-rate LAN separate from the high-rate science data.

Table 4 gives a concise overview of similar and different concepts for the planning and scheduling, and control and monitoring, functions.

4.4 DATA ACQUISITION AND PROCESSING

The data acquisition and processing operations concepts for the MODIS and HIRIS data systems have a fundamental difference with regard to routine processing: all data taken by the MODIS-N and MODIS-T instruments will be routinely processed through at least Level-3; data taken by the HIRIS instrument will only be processed beyond Level-1 as specified by the requestor.

Similarities

All standard processing will occur in the CDHF, and the CDHF will obtain any needed ancillary, correlative, or other data needed for standard processing.

The general nature of the Level-1 algorithms will be similar, especially for MODIS-T and HIRIS. The Level-1 data will be archived at the highest reversibly processed level (1A for MODIS, 1A2 for HIRIS).

Differences

Processing to support field experiments, i.e., near-real-time, is done by CDHF in the case of MODIS, and by the ICC or CAL for HIRIS. Standard HIRIS processing is done through Level-1 on all data. Beyond Level-1, only requested processing is performed. All MODIS data will be processed through level-3. MODIS data will be normally collected as part of routine surveys. HIRIS collects data primarily on request. MODIS has thermal-IR channels which will also be used for nighttime products. Algorithms and products which depend on the IR channels have no HIRIS counterpart.

Table 4
Similarities And Differences In MODIS and HIRIS Planning and Scheduling

FUNCTION/PROCEDURE	SIMILAR	DIFFERENT
Long-Term Planning and Scheduling	x	
Observation Request	x	
Request Through IST and IMC	x	
Conflict Resolution	x	
Planning Timeline	x	
Scheduling Timeline	x	
Conflict/Exception-Free Interactions	x	
Weekly Schedules	x	
Initial Schedule	x	
Simulation of Request	x	
Approved Schedule	x	
Commands Loads	x	
Target of Opportunity/Request Updates to Schedule	x	
Team Leader Approval of Request	x	
ICC Interfaces	x	
IMC Used for Request and Status	x	
DADS Used to Store Data	x	
DHC Used to Relay all Science Engineering, and Ancillary Data for Monitoring Health and Safety	x	
Commanding for Emergencies	x	
Instrument Behavior Analysis for Real-Time, Science, and Long-Term Trends	x	
Quick-Look Imagery	x	
Real-Time Monitoring	x	
Field Experiment Support	x	
Monitoring of Science Data	x	
Monitoring of Engineering Data	x	
Mission Planning Information	x	
HIRIS - Science Data Selected by Command for Separate Downlink		x
MODIS - Science Data Selected at GDS		x

4.4.1 Level-1 Processing and Calibration Processing

Similarities

Level-0 data will be available for Level-1 processing, for both MODIS and HIRIS, within 24 hours of instrument observation.

The type of algorithms used for Level-1 radiometric correction processing of HIRIS and MODIS data are quite similar.

Level-1 processing of HIRIS and MODIS data will need to be finished in the same time frames, both for normal systematic processing, as well as for instances demanding higher-priority processing.

Level-1 data will normally be archived and distributed in its radiometrically-corrected form (HIRIS Level-1A2, MODIS Level-1B). Specification of additional standard archival products at Level-1 will be driven by similar questions of calibration accuracy and radiometric-correction reversibility for both HIRIS and MODIS.

MODIS-T and HIRIS can be spectrally calibrated with similar algorithms, using atmospheric spectral absorption features.

Differences

MODIS and HIRIS data, as it emerges from the respective instruments, will be organized quite differently. This causes differences in packetization and in Level-1A processing.

MODIS data in its Level-1 form will not require spatial resampling. HIRIS data, however, will have some geometric distortions as it comes out of the instrument which may be significant enough for some uses to require correction. Thus, for HIRIS there may be a demand for a Level-1B product not yet defined that has undergone irreversible spatial resampling.

4.4.2 Level-2 Processing

Similarities

Retrieval of environmental variables from imaging spectrometry data is a relatively new and rapidly-evolving field of investigation. Thus, Level-2 algorithms for both HIRIS and MODIS are likely to change dramatically and expand in both applicability and capability over the next 15 years. Retrieval algorithms that use reflected solar radiation data, of relevance to a given scientific field, are likely to be similar between HIRIS and MODIS.

Differences

All MODIS data will undergo Level-2 processing. HIRIS data is likely to undergo Level-2 processing only upon request.

Spatial mixing of ground reflectivity information, due to atmospheric scattering, is a far more serious problem in HIRIS imagery than in MODIS imagery because of the higher spatial resolution of HIRIS. This puts more demands on the atmospheric correction algorithms used in HIRIS Level-2 software.

Retrieval of atmospheric properties will be a major purpose of MODIS Level-2 algorithms, while it will be of less interest for HIRIS Level-2 algorithms. MODIS-N will have many channels designed for the retrieval of specific atmospheric properties. HIRIS and MODIS-T will have no such intentionally-designed channels, although both will have capabilities for the retrieval of atmospheric properties.

The correction of HIRIS data for topographic effects will be more important than for MODIS, due to the more extreme slopes found on smaller spatial scales.

Retrieval of topographic maps from stereo HIRIS imagery may be an important type of Level-2 processing. This will be a very minor effort for MODIS.

4.4.3 Level-3 Processing

Similarities

Processes will be used to resample Level-1 and 2 data on standard mapping grids will be similar for MODIS and HIRIS.
Many investigations will make use of collocated HIRIS and MODIS Level-3 data.

Differences

All MODIS data will undergo Level-3 processing. HIRIS data will be processed through Level-3 only upon request.

MODIS data, as delivered from the platform with current predicted platform stability will be correctly Earth-located to within 1/10 pixel. This is not likely to be the case for most HIRIS data.

4.4.4 Post-Archival Processing

Similarities

Because algorithms for MODIS and HIRIS Level-2 processing will be evolving so rapidly, there is likely to be a strong demand for reprocessing archived data using new algorithms.

Differences

Because MODIS will produce a consistent global data set, it may well be that all (or a large portion) of the archived MODIS Level-1 data will be reprocessed into Level-2 products when there is a major change in the MODIS Level-2 algorithms or calibrations. It is currently assumed, based on the presumed lower demand for higher-level products, that HIRIS Level-1 data will undergo new Level-2 processing only for validation purposes and in response to specific requests.

4.4.5 Near-Real-Time Processing

Neither the HIRIS nor the MODIS ground data systems will process the data in an operational manner; however, the two data systems will support the near-real-time processing of a subset of the data (i.e., in support of field experiments).

HIRIS will need a standard product for the evaluation of cloud cover at Level-1. There is no similar requirement for MODIS.

4.5 CALIBRATION AND VALIDATION

4.5.1 Similarities

The MODIS TMCF node at GSFC and the HIRIS CASSL seem to have nearly equivalent calibration support roles within their data systems. Both will be staffed by similar professionals, such as science team members, instrument engineers, and software engineers. A group of software engineers will support the transition of science algorithms from the TMCF environment to the CDHF environment and will develop software of general utility to all science team members.

The MODIS CST and HIRIS Engineering team at the CAL have nearly equivalent functions. Their activities include the development of calibration algorithms, updating of the calibration coefficients, and the comparison of data from different instruments.

MODIS and HIRIS will have team members with similar distributions of interests in agronomy, forestry, glaciology, hydrology, oceanography, and plant ecology.

HIRIS will be designed and partly built by JPL. MODIS will be partly designed and built by GSFC. Thus, for the purposes of calibrating and characterizing the MODIS and HIRIS instruments, both science teams will have some access to the engineers responsible for the design and construction of their instrument. Both HIRIS and MODIS have identified a need for operations-phase instrument engineering support.

Both HIRIS and MODIS identify a requirement for algorithm validation support facilities independent of the production CDHF facility.

4.5.2 Differences

The MODIS team leader has been assumed to be located at GSFC, as will the CST, the CDHF, the DADS, and the ICC/IST. The HIRIS team leader has been assumed to be located at a site remote from JPL, the CASSL and ICC will be at JPL, and the CDHF and DADS will be remote from both.

The MODIS TMCF's are involved with calibration, scientific algorithm development, validation of data, and generation of specialized data products. The HIRIS CAL is involved only with calibration. The HIRIS TMCFs support the remaining functions.

MODIS-N has thermal-infrared channels which HIRIS does not have. Thus, MODIS will have calibration and scientific algorithms which have no equivalent counterpart for HIRIS.

4.6 DATA ARCHIVE AND DISTRIBUTION

4.6.1 Similarities

Both systems will provide a facility for archiving science data sets and related science and engineering data products, as generated by the CDHF. Specialized products from science team members are also received and stored. This same facility will be responsible for distributing this data to requesting users. The algorithms used for MODIS and HIRIS Level-2 (and above) processing will be expected to evolve rapidly, leading to a potentially heavy demand for reprocessing. This will lead to high levels of data transmission from the DADS to the CDHF or other reprocessing facilities. User requests will be interactively processed through the IMC, with standing orders scheduled periodically by the DADS.

4.6.2 Differences

MODIS products will be of more interest to the atmospheric science and oceanographic science communities, while HIRIS products will be of more interest to the geological science community. MODIS data will cover the entire Earth in short time intervals, with more MODIS data expected to be available for a given region than HIRIS data. As MODIS will produce all of its products prior to possible user query, its DADS will be able to provide data sets upon user request.

The HIRIS DADS will need a data set production initiation mechanism to satisfy requests for Level-2 (and above) products that have yet to be produced. MODIS users will have a wider range of existing data sets and may be able to respond more quickly to requests using data from this inventory.

MODIS will produce a consistent global data set. Whenever there are major changes to Level-2 (and above) processing algorithms, reprocessing of the Level-1 data stored in the DADS may be required. Due to the expected lower demand for Level-2 and higher HIRIS data products, HIRIS Level-1 data will be retrospectively processed into new Level-2 and above products less frequently than MODIS.

4.7 USER ACCESS

4.7.1 Similarities

Descriptive data, such as browse, catalog, and metadata, will be available for use as query criteria. Browse data will be available for transmission to the user's terminal or shipment via off-line media. Users will be able to request information on queries still being processed, and determine their remaining account balances. Prior to executing a query, the IMC/DADS will notify the user of the number of images being requested and the cost (if any) of the media and its shipping. Both HIRIS and MODIS will ship requested data sets within one business day of receipt of request.

Both HIRIS and MODIS science users will be able to submit data acquisition requests. These address planned investigations requiring HIRIS/MODIS data products not already produced or producible from existing data. Requests are routed through channels for approval and the generation of the platform and/or instrument command sequences necessary for gathering the data is performed.

MODIS and HIRIS browse data are available interactively from the IMC.

4.7.2 Differences

No significant differences are noted in this area.

5. SYSTEM SPECIFICATIONS COMMONALITY

5.1 DATA SYSTEM SPECIFICATIONS COMMONALITY

The HIRIS and MODIS data systems interface with a common set of external support facilities that includes platform on-board processing, the DHC, the EMOC, the IMC, other EosDIS DADS, Non-Eos data sources, long-term archives, and users. A dedicated high-rate Level-0 processing facility associated with the DHC may process Level-0 HIRIS data.

Examination of these interfaces reveals an essential commonality of function between the proposed HIRIS and MODIS systems. Differences that were found relate to data flow rates or the frequency with which a given support function might be accessed, but not to the overall need for both systems to support the same set of system functions. Differences that do exist between the HIRIS and MODIS external interfaces arise primarily in the use of the extra science stream HIRIS creates on-board and in Level-0 processing within the ground data system.

HIRIS is an observatory instrument capable of high resolution observations and high instantaneous data rates. MODIS is a survey instrument with lower spatial resolution and

a lower instantaneous data rate, but operated nearly continuously. Differences in required data system functions and capacity arise as a result of these fundamental instrument differences.

Since the HIRIS instrument is generally used only for targets of special interest, instrument control plays a large role in the HIRIS system. Ramifications include an increased HIRIS need, relative to MODIS, for conflict resolution when instrument observations are planned, an increased need for computing resources to generate and verify instrument command uploads, an increased data flow rate on the command uplink, and an increased need to process and store commands on board the platform for execution at a later time.

As presently projected, MODIS data will flow through the on-board LAN that supports low and medium-rate instruments on the platform. MODIS data will be intermingled with data from these other instruments for transfer from the spacecraft to ground facilities. The DHC recovers the original MODIS instrument data stream and supplies the instrument data to the data system.

Because of the instrument's high instantaneous data rate, HIRIS data will not be routed through the on-board LAN. Instead, data will be transferred in dedicated HIRIS data packets. These packets can be routed to a separate Level-0 processing facility associated with the DHC that is not required to process data from all instruments. The HIRIS data system will receive its primary data from this facility. HIRIS will create a second separate stream on board, which will flow through the LAN and be used on the ground to support quick-look requirements.

5.2 IST SPECIFICATIONS COMMONALITY

5.2.1 Similarities

For both MODIS and HIRIS, routine coordination of the requests employs the ICC in support of the team leader's tasks in instrument planning, easing the load on the IST and the team leader. This reduces the IST workload to requests originating from the science team or for those cases where the team leader must participate directly.

5.2.2 Differences

The usage of the IST varies between the two instruments. HIRIS will have a larger number of data acquisition requests than MODIS, since it is request-driven, with a large proportion coming from users external to the science team.

5.3 ICC SPECIFICATIONS COMMONALITY

5.3.1 Similarities

Both HIRIS and MODIS ICC specifications are driven by 24-hour-a-day operations and the timeliness of science and engineering displays for instrument monitoring.

Both ICCs have the same interfaces with EosDIS and with internal GDS elements.

Both the HIRIS and MODIS traffic analyses follow along the same lines. Both analyses show approximately the same order of magnitude of traffic of the same type, with the exception of quick-look science data. Clearly, this is due to the HIRIS on-board subsampling mentioned earlier.

5.3.2 Differences

The outstanding differences in traffic between HIRIS and MODIS are in the areas of instrument science monitoring and data request volume.

The worst-case HGDS low-rate science monitoring data volume is 50 MB/day. The MODIS GDS, however, must sub-sample on the ground, therefore the equivalent worst-case would require processing the entire MODIS science data stream, or about 10^{11} bytes/day. Also, the MODIS specification addresses this data volume in the context of the quick-look timeliness requirement.

HIRIS must support planning, scheduling, and commanding to fulfill 7,200 data acquisition requests per month. MODIS will support only on the order of 100 special requests per month, which will involve calibration events and non-standard tilt request scenarios for MODIS-T.

5.4 TMCF SPECIFICATIONS COMMONALITY

5.4.1 Similarities

Both MODIS and HIRIS require image analysis capabilities.

Both MODIS and HIRIS require the disk storage of some data within the TMCF/CST and CASSL/CAL for calibration purposes.

Both MODIS and HIRIS require the capability to import and analyze data from each other, and from other satellite instruments, as part of their validation studies.

Both MODIS and HIRIS software, either developed in-house or acquired commercially, must adhere to EosDIS standards.

The CDHF computer architectures may employ vector or parallel processors. The TMCF's may have different computer architectures. However, the TMCF's are expected to produce software transportable among the EosDIS environments.

The TLCF at GSFC or the CASSL at JPL provides an environment matching that of the CDHF, accessible to the science team for software transition from the TMCF to the CDHF environment; i.e., acting as a beta test facility where cooperative validation of the processing algorithms takes place prior to the authorization of the software for standard product generation at the CDHF.

5.4.2 Differences

There are no significant differences in this area.

5.5 CDHF SPECIFICATIONS COMMONALITY

Similarities

Both systems will be required to use commercially available hardware in a modular architecture. Both systems will be designed to allow significant expansion. Both systems will be designed to allow upgrade or replacement of elements.

Both systems can employ the same types of hardware:

a. Higher Level-processors with heavy duty number-crunchers and array processing or vector processing support.

b. Parallel processors.

c. High-performance workstations.

Differences

MODIS will require a larger total processing capacity.

5.5.1 Real-Time and Quick-Look Design

MODIS near-real-time data are extracted by the CDHF on the ground from the full-resolution science data stream to support field experiments.

5.5.2 Processing Technology Issues

MODIS and HIRIS have used modular approaches in specifying the CDHF:

a. The HIRIS CDHF specification is based on use of loosely coupled mid-size supercomputers for Level-2+ processing and smaller processors for Level-1 processing.

b. The MODIS CDHF specification is based on the use of large capacity processors (supercomputers).

Data volume and process sizing has been significant in determining these specifications, but neither architectural approach is necessarily the only alternative. However, the more important aspect in specifying the system architecture is that the system be highly modular to allow future upgrades.

5.6 DADS SPECIFICATIONS COMMONALITY

Orders for HIRIS data products will generally be placed for individual scenes or for a relatively small set of scenes. Some requestors will require large numbers of HIRIS scenes. With global coverage and a repeat period of as little as one day, individual orders for MODIS data will consist of volumes ranging between 10^9 to 10^{11} bytes. The smaller orders for MODIS data will be equivalent to the typical order for a HIRIS scene.

5.6.1 Similarities

Both systems will store Level-1 and higher science data products generated by the CDHF. Specialized data products will be generated and sent to the DADS by scientists. A DADS will be collocated with each CDHF and accessed interactively by most users through the IMC. A standardized format will be used for descriptive data such as browse, catalog, and metadata, as well as the science products. At predetermined intervals, the DADS will send science product data sets to a long-term archive, purging these products from the DADS facilities.

HIRIS and MODIS will provide descriptive data for all products generated.

Standard data product formats must be similar.

Browse data will be instrument unique, but the browse data format must be similar or identical.

Metadata/catalog data formats must be identical.

5.6.2 Differences

MODIS data users will request greater data quantities than HIRIS data users.

5.6.3 Specialized Product Archiving

The proportions of specialized products received at the DADS for archiving is substantially different:

a. For HIRIS, generation of standard products beyond Level-1 will be on request only. Many HIRIS higher-level products will be produced initially as special products by specialized computing facilities; all of these products must be archived.

b. The full MODIS data set will be processed to at least the Level-3 at the CDHF. MODIS is anticipated to generate many more standard high-level products (Level-2 and above) than HIRIS, at least initially, with a proportionately smaller amount of specialized products generated external to the CDHF and subsequently submitted to the DADS for archiving.

APPENDIX A
ACRONYMS

CAL	Calibration Analysis Laboratory
CASSL	Calibration Analysis and Science Support Laboratory
CDHF	Central Data Handling Facility
CDOS	Customer Data and Operations System
CST	Calibration Support Team
DADS	Data Archive and Distribution System
DHC	Data Handling Center
EMOC	EOS Mission Operations Center
EOS	Earth Observing System
EosDIS	Eos Data Information System
GDS	Ground Data System
GSFC	Goddard Space Flight Center
HGDS	HIRIS Ground Data System
HIRIS	High Resolution Imaging Spectrometer
ICC	Instrument Control Center
IIWG	International Investigator Working Group
IMC	Information Management Center
IR	Infrared
IST	Instrument Support Terminal
IWG	Investigator Working Group
JPL	Jet Propulsion Laboratory
LAN	Local Area Network
Mbps	Megabytes per second
MIDACS	MODIS Information, Data, and Control System
MODIS	Moderate Resolution Imaging Spectrometer

MODIS-N	MODIS Nadir
MODIS-T	MODIS Tilt
NASA	National Aeronautics and Space Administration
PSC	Platform Support Center
TDRSS	Tracking and Data Relay Satellite System
TLCF	Team Leader Computing Facility
TMCF	Team Member Computing Facility
TOO	Target of Opportunity
VNIR	Visible and Near Infrared Detector

NASA
National Aeronautics and Space Administration

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16. Abstract
The High Resolution Imaging Spectrometer (HIRIS) and Moderate Resolution Imaging Spectrometer (MODIS) Data Systems Working Group was formed in September 1988 with representatives of the MODIS Data System Study Group and the HIRIS Project Data System Design Group to collaborate in the development of requirements on the EosDIS necessary to meet the science objectives of the two facility instruments. A major objective was to identify and promote commonality between the HIRIS and MODIS data systems, especially from the science users' point of view. A goal was to provide a base set of joint requirements and specifications which could easily be expanded to a Phase-B representation of the needs of the science users of all EOS instruments. This document describes the points of commonality and difference between the Level-II Requirements, Operations Concepts, and Systems Specifications for the ground data systems for the MODIS and HIRIS instruments at their present state of development.

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